

An Adaptive Plan for Managing Alewife
in the St. Croix River Watershed, Maine and New Brunswick

Submitted to:

International St. Croix River Watershed Board,
International Joint Commission

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An ad hoc management plan work group
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Date:

April 23, 2010

INTRODUCTION

This management plan was drafted at the request of the International Joint Commission's International St. Croix River Watershed Board. Based on the best available science, it outlines an adaptive process for restoring alewife (gaspereau) to the portion of the St. Croix watershed (Maine/New Brunswick) that lies *below* (downstream of) West Grand Lake and Spednic Lake (Figure 1) while maintaining the smallmouth bass fishery at current or higher quality. The plan is the consensus of the contributors; however, their participation does not constitute their agency's endorsement.

History of St. Croix Alewife and Smallmouth Bass Management

Both alewife (*Alosa pseudoharengus*) and smallmouth bass (*Micropterus dolomieu*) currently inhabit the international St. Croix River system of Maine and New Brunswick. Alewives, a species native to the St. Croix River, were once harvested in great numbers (Atkins 1887, Perley 1852). They have an anadromous life history that includes repeat spawning (Flagg 2007), with ecological roles in the food webs and nutrient cycles of marine, freshwater, and terrestrial systems (IJC 2005). Dams and water pollution reduced the St. Croix's anadromous fish runs beginning in the 1860s. Smallmouth bass were first stocked in the St. Croix watershed in LaCoute Lake in Vanceboro in 1877 (Warner 2005). By 1900, they provided an attractive sport fishery in Big Lake (Watson 1965), and much of the rest of the watershed. They are long-lived repeat spawners that during the course of becoming a naturalized population altered the ecology in many parts of the watershed.

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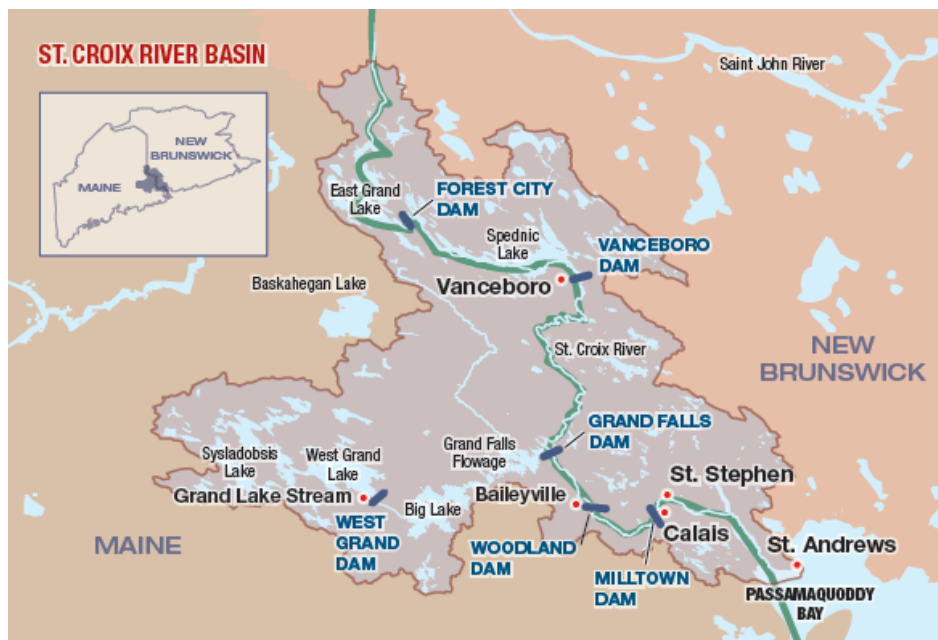


Figure 1. Map of the St. Croix watershed, with selected towns, dams, and lakes in Maine and New Brunswick identified (provided by International Joint Commission).

By the early 1980's improved fish passage and water quality in the St. Croix system resulted in an increasing alewife spawning population. This was perceived to have contributed to declining numbers of juvenile bass and poor quality smallmouth bass angling in Spednic Lake. A number of management changes were made simultaneously to address this decline, including blocking alewives from Spednic Lake beginning in 1987, which made it impossible to determine the relative impact of each action. In 1991, American and Canadian fisheries agencies began an alewife production assessment in the lower St. Croix watershed by temporarily blocking alewife passage at Grand Falls Dam. The temporary blockage was to end in 1995, however, the Maine Legislature prohibited alewife passage at the Woodland and Grand Falls fishways (12 MRSA§6134, 1995). This eliminated alewife access to over 98% of the species' projected St. Croix spawning habitat (Anonymous 1993). The stock declined from 2.6 million returning alewives in 1987 to only 900 in 2002 (St. Croix International Waterway Commission 2009). When efforts to change Maine's 1995 St. Croix alewife blockage law failed in 2001, Department of Fisheries and Oceans, Canada (DFO) began trucking a portion of the river's alewife run around the Woodland Dam.

A recent research project and review of scientific data on St. Croix alewife and smallmouth bass populations found no negative effects of alewives on St. Croix smallmouth bass populations below Spednic Lake (Maine Rivers 2006). The study served as a catalyst for renewed efforts to change Maine law that resulted in the Woodland fishway being reopened in 2008 (12 MRSA §6134, 2007). In May 2009, Maine and New Brunswick conservation interests petitioned the United States/Canada International Joint Commission to re-open all of the St. Croix's boundary dam fishways to alewife passage under the auspices of the 1909 Boundary Waters Treaty. In November 2009, the International Joint Commission responded by

asking the inter-agency St. Croix Fisheries Steering Committee to develop an adaptive management plan for restoring alewives to the St. Croix system.

Jurisdictional Authorities

The St. Croix Fisheries Steering Committee assembled an ad hoc work group to prepare this adaptive management plan with representatives from the following fisheries management agencies (listed in alphabetical order of acronym):

Fisheries and Oceans Canada (DFO) is responsible for developing and implementing policies and programs in support of Canada's scientific, ecological, social and economic interests in oceans and fresh waters. The Department's guiding legislation includes the *Oceans Act*, which charges the Minister with leading oceans management and providing coast guard and hydrographic services on behalf of the Government of Canada, and the *Fisheries Act*, which confers responsibility to the Minister for the management of fisheries, habitat and aquaculture. The Department is also one of the three responsible authorities under the *Species at Risk Act*. DFO's fisheries management program works to manage fisheries according to credible, science-based, affordable and effective practices, to protect and conserve fisheries resources, and to provide Canadians with a sustainable fishery resource that provides for an economically viable and diverse industry. DFO is guided by the Precautionary Approach (being cautious but not using uncertain or inadequate scientific information as a reason to postpone or fail to take action). DFO has outlined the minimal requirements for a harvest strategy to be compliant with the Precautionary Approach (DFO 2009).

Maine Department of Marine Resources (DMR) was established by State Statute (Title 12 Parts 4, 9) to conserve and develop marine and estuarine resources; to conduct and sponsor scientific research; to promote and develop the Maine coastal fishing industries; to advise and cooperate with local, state and federal officials concerning activities in coastal waters; and to implement, administer and enforce the laws and regulations necessary for these enumerated purposes. Within DMR, the Bureau of Sea Run Fisheries and Habitat (BSRFH) has responsibility for diadromous species management. Shad and river herring management authority is coordinated through the Atlantic States Marine Fisheries Commission (ASMFC), with river herring management in Maine guided by AMENDMENT 2 (ASMFC 2009) to the Atlantic States Marine Fisheries Commission, Interstate Fishery Management Plan for Shad and River Herring. The ASMFC developed the amendment under the authority of the Atlantic Coastal Fisheries Cooperative Management Act.

New Brunswick Department of Natural Resources (DNR) shares responsibility with Fisheries and Oceans, Canada for freshwater fisheries management. As described in the "Canada - New Brunswick Memorandum of Understanding on Recreational Fisheries", New Brunswick has the primary responsibility for managing recreational fisheries for 19 freshwater fish species; including landlocked Atlantic salmon, smallmouth bass and trout species. Legislation for these species is included in the Federal Fisheries Act and the Maritime Provinces Fisheries Regulation.

Maine Department of Inland Fisheries and Wildlife (MDIF&W) was established by State Statute (Title 12 Parts 3, 10, 13) as stewards of Maine's inland fisheries and wildlife; to protect

and preserve Maine's natural resources, quality of place, and economic future. The Fisheries Division has the responsibility of managing recreational fisheries for freshwater fish species; including landlocked Atlantic salmon, smallmouth bass, and trout species. This management is guided by species plans, developed in consultation with the angling public.

NOAA's National Marine Fisheries Service (NOAA Fisheries Service) is dedicated to the stewardship of living marine resources through science-based conservation and management, and the promotion of healthy ecosystems. As a steward, NOAA Fisheries Service conserves, protects, and manages living marine resources in a way that ensures their continuation as functioning components of marine ecosystems, affords economic opportunities, and enhances the quality of life for the American public.

In 2006, NOAA Fisheries Service listed river herring (alewife and blueback herring) as a Species of Concern. This designation does not carry any procedural or substantive protections under the Endangered Species Act. However, the list is intended to: identify species potentially at risk; identify data deficiencies and uncertainties in species' status and threats; increase public awareness about those species; stimulate cooperative research efforts to obtain the information necessary to evaluate species status and threats; and, foster voluntary efforts to conserve the species before listing becomes warranted. Efforts to conserve species for which NOAA Fisheries Service has concerns are supported by the Proactive Conservation Program. Funding for projects led by state and territory management agencies is available through NOAA's Proactive Species Conservation Grant Program. Additional funding for NOAA biologists working on research or conservation projects to improve the status of Species of Concern is available through our Internal Grant Program.

U.S. Fish and Wildlife Service (USFWS) is committed to working with others to conserve, protect and enhance fish, wildlife, and plants and their habitats for the continuing benefit of the American people. USFWS supports native diadromous fisheries conservation through many collaborative mechanisms, including the North Atlantic Landscape Conservation Cooperative (NALCC), National Fish Habitat Action Plan (NFHAP), Atlantic Coast Fish Habitat Partnership (ACFHP), USFWS Interjurisdictional Commissions, USFWS Coastal Program, Atlantic States Marine Fishery Commission (ASMFC) and the Ocean Action Plan. Their role in fisheries management is primarily mandated by the Magnuson Stevens Fishery Conservation and Management Act, the Anadromous Fish Conservation Act, the Atlantic Coastal Fisheries Cooperative Management Act. In addition, the Fish and Wildlife Coordination Act of 1934, Fish and Wildlife Act of 1956, Federal Aid in Sport Fish Restoration Act, Fishery Conservation and Management Act of 1976, and International Boundary Waters Treaty of 1909 authorize the U.S. Fish and Wildlife Service to participate in a various capacities specific to each law. Technical assistance and funding for projects are available through the USFWS Coastal Program, Partners Program, Fisheries National Fish Passage Program, as well as grants that are listed at [grants.gov](https://www.grants.gov).

AQUATIC HABITAT AND FISH PASSAGE IN THE ST. CROIX WATERSHED

The St. Croix River forms the boundary between the Province of New Brunswick, Canada and the State of Maine, U.S.A. for approximately 110 miles (185 km) from headwater to tidewater

(Figure 1). This transboundary basin is approximately 1,649 miles² (4,271 km²) in area and has 183 tributary streams and 61 lakes in the system. Of these, 20 lakes were identified by the plan contributors as accessible to alewife spawners in the portion of the watershed covered by this plan (Table 1). River segments were not included in calculations of alewife habitat because agencies in both countries focus alewife management on lakes. Thus, only the areas of these lakes (Table 1) were used to estimate potential alewife production. As more information about lake access becomes available or as fishways are built, the amount of alewife spawning habitat will be updated. Smallmouth bass inhabit much of the St. Croix watershed, including at least twelve lakes that provide alewife spawning habitat (Table 1).

Up and downstream fish passage facilities at dams affect the movement of alewives and smallmouth bass in the watershed. This plan focuses on the five major dams and is based on: 1) fishways at Milltown, Woodland, and Grand Falls dams on the St. Croix River allowing spawning alewives upstream; and 2) fishways at West Grand and Vanceboro dams being closed to spawning alewives. Fishways at small dams on Canoose Flowage and King Brook Lake are thought to provide alewife spawners access to these lakes (Table 1) and the lack of a fishway prevents alewife access to others, including Clifford Lake, Hosea Pug Lake, and Silver Pug Lake.

Fishway design affects the ability of fishways to effectively pass large numbers of fish. Watt (1987a) found the rate and timing of daily alewife passage at Milltown depended on the number of fish in the spawning population and estimated that the maximum fishway capacity was 106,300 (\pm 800) fish per day. This and other estimates (White and Watt 1989) match the original fishway design capacity of 100,000 fish daily. White and Watt (1989) concluded that the capacity of the Milltown fishway occasionally limited the rate of alewife migration to the river.

Once alewives have passed Milltown, their ability to reach most of the spawning lakes in the watershed depends on the effectiveness of the next two fishways. Both have a maximum capacity lower than the Milltown fishway; 87,000 alewives/day for Woodland and 40,500 alewives/day for Grand Falls (Personal communication from K. Spears, Georgia Pacific to L. Flagg, DMR 1988). The numbers of alewives passing Woodland and Grand Falls fishways in 1984, 1985, and 1986 (Personal communication from K. Spears, Georgia Pacific to L. Flagg, DMR 1988) were used to estimate the percentages of fish passing each dam and staying in the reaches below the two dams (Table 2). Annually between 23.6 % and 42.5 % of the total run passed Grand Falls gaining access to the majority of the St. Croix's alewife spawning habitat, and 34.5% to 74.8% of the run remained below Woodland, where there was limited spawning habitat (Table 2). While fish passage was not a term of reference of this plan, passage issues were introduced so they can be assessed and addressed by fisheries agencies.

Adult and juvenile alewives migrating downstream may pass over spillways or through gates, turbines, fishways, in addition to downstream passage facilities. While all of the lower St. Croix mainstem dams have downstream passage facilities, Rizzo et al. (1989) reported that improvements should be made to downstream passage at Grand Falls. Watt (1987b) and others have expressed concerns about downstream passage at Milltown. High fish mortality at ineffective downstream passage facilities can limit the recovery of alewife populations.

Table 1. Lakes within the portion of the St. Croix watershed (Maine and New Brunswick) that are downstream of West Grand Lake and Spednic Lake and are considered alewife spawning habitat; included are lake area and documented presence of smallmouth bass.

Reach	Waterbody	Jurisdiction	Area		Bass
			Hectare	Acre	
Milltown > Woodland					
	Tyler Mills Flowage	ME	7	17	√
	Howard Mills Flowage	ME	17	42	√
	Kendricks Lake	NB	31	77	
	Potters Lake	NB	47	116	√
Woodland >Grand Falls					
	Woodland Flowage	Int'l	475	1,174	√
Grand Falls > West Grand					
	Grand Falls Flowage	Int'l / ME	2,708	6,691	√
	Lewy Lake	ME	136	336	√
	Long Lake	ME	241	595	√
	Big Lake	ME	4,170	10,305	√
	Unnamed pond in T1R1 (on Kennebeck Brook)	ME	13	32	
	West Musquash Lake	ME	653	1,613	
	East Mushquash Lake	ME	326	806	√
	Little River Lake	ME	30	74	√
Grand Falls > Spednic					
	King Brook Lake	NB	36	90	
	Hound Brook Lake	ME	57	140	
	Simsquish Lake	ME	47	115	
	Canoose Flowage	NB	647	1,600	√
	Upper Canoose Flowage	NB	65	160	
	Mud Lake	NB	20	50	
	Lambert Lake	ME	245	605	√
TOTAL - ALL Reaches			9,971	24,638	
TOTAL - Reaches ABOVE GRAND FALLS			9,394	23,212	

Table 2. Estimated numbers of alewives passing the lower three dams on the St. Croix River, with the percent of the number passing the dam downstream and percent of total run remaining in the reaches between dams. Data for 1986 included a range and median, only the median was used in these calculations.

Dam	1984	1985	1986
	Total	Total	Median
Estimated Alewives passing:			
Milltown	153,000	369,000	1,985,000
Woodland	78,000	93,000	1,300,000
Grand Falls	65,000	87,000	625,000
Percent passing:			
Woodland that passed Milltown	51.00%	25.20%	65.50%
Grand Falls that passed Woodland	83.30%	93.50%	48.10%
Percent in reaches:			
Milltown to Woodland	49.00%	74.80%	34.50%
Woodland to Grand Falls	8.50%	1.60%	34.00%
Above Grand Falls	42.50%	23.60%	31.50%

ALEWIFE (GASPEREAU) POPULATION AND FISHERY

Status of the Population

Since monitoring began in 1981, the annual alewife return to the St. Croix has varied from 900 to 2.6 million fish. More recently (from 2000 to 2009), an average of 7,134 adult alewives (~5 alewives/acre ~ 12 fish/hectare based on approximately 1,400 accessible surface acres or 566 hectares) passed the Milltown Dam fishway to spawning migration in lakes below the Grand Falls Dam, with the largest run (11,829) occurring in 2006. From 2001 to 2007 approximately 70% of each run was trucked and released into the Woodland Flowage, an average of 3,812 spawners (~3 alewives/acre or 7 fish/hectare) in that portion of the St. Croix watershed. There is currently no commercial alewife fishery in the watershed and any new fishery in Maine would need to be consistent with ASMFC guidance.

Population Goal Considerations

Historic changes in access to spawning habitat make it difficult to envision the size of a restored St. Croix alewife population or the number of spawners needed to maintain it. Establishing an estimate of the minimum number of spawning alewife for lake habitat (Table 1) included in this plan requires: 1) an estimate of the carrying capacity of the habitat and 2) criteria for establishing a minimum spawning population size. Neither is currently known for the St. Croix watershed, although general information about alewife, as well as regional proxies, are available that could be used to establish the goal. However, given that abundance is currently very low, and because this plan can be started without establishing a long-term goal, the decision on how to calculate a goal has been deferred until more watershed-specific data are gathered as the plan is implemented. The following information provides an approach to calculating and a rough approximation of that goal.

Carrying capacity of alewife habitat has been estimated by Gibson and Myers (2003a, 2003b) based on meta-analyses of on eight alewife populations in New England and Atlantic Canada. These estimates can be used when watershed-specific data are not available, but also demonstrates that alewife habitat carrying capacity is highly variable among rivers. Based on their analyses, “typical” habitat (the median: $\frac{1}{2}$ of the rivers would have higher capacities and $\frac{1}{2}$ lower) has a carrying capacity of 55 mt/km² (0.24 t/acre), but 10% of rivers would be expected to have carrying capacities below 33 mt/km² (0.15 t/acre) and 10% would be expected to have a capacity greater than 93 mt/km² (0.41 t/acre) If the St. Croix River is “typical”, these values would imply that the carrying capacity of the accessible habitat under this plan would be 23.4 million alewife (Table 3), a value that is high relative to other estimates for this portion of the watershed. White and Squires (1989) estimated the range of carrying capacity for the same portion of the watershed to be 7.5 million to 9.5 million alewife, and estimates of the carrying capacity of the entire watershed (roughly 4 times the area to which access will be provided under this plan) were 20 million alewife (Watt 1987) and 23.6 million alewife (Flagg 2007). However, these older estimates were based on the carrying capacity of heavily exploited systems and it is not clear that the analyses fully accounted for the influence of commercial fishing.

Spawning escapement reference levels for fisheries are often presented as some portion of the unfished equilibrium spawner biomass. The unfished equilibrium spawner biomass is the population size at which abundance would stabilize in the absence of random variability (and fishing) if all vital rates (growth, survival, maturation, and reproduction) remained unchanged, a value largely dependent on carrying capacity. The proportion of this value to be used as a minimum can be obtained from management plans for alewife in other areas (Atlantic States Marine Fisheries Commission 2009, DMR and MDIF&W 2009) or from reference points used for other species (e.g. Beddington and Cooke 1983, Goodyear 1993). Given their high productivity, a value of 20% of the unfished equilibrium spawner biomass might be considered appropriate for alewife to calculate an initial minimum spawning escapement goal. If the St. Croix River is typical of the rivers in the meta-analysis, the spawning escapement goal would be 4.5 million alewife based on this proportion (Table 3).

Table 3. Potential carrying capacity and minimum spawning escapement goals (number of alewives) calculated by lake area within the St. Croix River watershed included in the plan. See text for details.

Reach	Waterbody	Area		Carrying Capacity	Spawning Escapement
		Hectare	Acre		N20%
Milltown > Woodland					
	Tyler Mills Flowage	7	17	16,569	3,157
	Howard Mills Flowage	17	42	40,239	7,667
	Kendricks Lake	31	77	73,377	13,981
	Potters Lake	47	116	111,249	21,197
Woodland >Grand Falls					
	Woodland Flowage	475	1,174	1,124,325	214,225
Grand Falls > West Grand					
	Grand Falls Flowage	2,708	6,691	6,409,836	1,221,308
	Lewy Lake	136	336	321,912	61,336
	Long Lake	241	595	570,447	108,691
	Big Lake	4,170	10,305	9,870,390	1,880,670
	Unnamed pond in T1R1 (on Kennebeck Brook)	13	32	30,771	5,863
	West Musquash Lake	653	1,613	1,545,651	294,503
	East Mushquash Lake	326	806	771,642	147,026
	Little River Lake	30	74	71,010	13,530
Grand Falls > Spednic					
	King Brook Lake	36	90	85,212	16,236
	Hound Brook Lake	57	140	134,919	25,707
	Simsquish Lake	47	115	111,249	21,197
	Canoose Flowage	647	1,600	1,531,449	291,797
	Upper Canoose Flowage	65	160	153,855	29,315
	Mud Lake	20	50	47,340	9,020
	Lambert Lake	245	605	579,915	110,495
TOTAL - ALL Reaches		9,971	24,638	23,601,357	4,496,921
Reaches ABOVE GRAND FALLS		9,394	23,212	22,235,598	4,236,694

There is considerable uncertainty about whether habitat in the St. Croix River is typical of the rivers in the meta-analysis. It is unlikely all lakes in the watershed below Spednic Lake and West Grand Lake have the same productive potential and lower or higher values might be applied to specific lakes if more data were available. Further, overall habitat potential in the watershed may be compromised by predation, downstream mortality, upstream passage effectiveness, and conditions controlling ocean survival. Although the projected carrying

capacity and minimum spawning escapement are based on the best available science and management criteria available at the time of writing, their applicability to the St. Croix River is not known.

Timelines for Rebuilding

Alewife are highly productive and, under ideal conditions, it is possible that the St. Croix River population could rebuild from the 2009 count of 10,450 fish to over 2 million fish within 10 years as it did in the 1980's. However, there is also the possibility that it will recover more slowly or perhaps not rebuild at all. Recent spawning runs have had few repeat spawners. These older spawners have more eggs than first-time spawners, and their absence will reduce population growth rates compared to those seen in the past.

This plan will control the rebuilding of the St. Croix's alewife population through advances, holds, and reductions in annual alewife spawner targets determined by the response of the smallmouth bass population. If alewife abundance does not increase as the plan is implemented, then factors limiting recovery will need to be identified and addressed. This could include comparing population trajectories with nearby populations (to evaluate wide scale effects), assessing freshwater production by monitoring juveniles, and evaluating fish passage survival.

SMALLMOUTH BASS POPULATION AND FISHERY

Status of the Bass Sport Fishery

The relative level of use among lakes reflects angler satisfaction with catch rates and/or size quality and may be considered an integrated measure of fishery quality. MDIF&W conducted aerial counts of anglers on 13 eastern Maine bass lakes in 2003 to estimate angler use for the open water fishing season. Big Lake, with 7,667 angler-days of use (0.74 angler-days/acre or 1.84 angler-days/hectare) had the highest observed angler use for these bass lakes, and Grand Falls Flowage, with 4,093 angler-days of use (0.61 angler-days/acre or 1.36 angler-days/hectare) had the second highest angler use. Angler use at West Grand Lake (0.42 angler days/acre or 1.05 angler-days/hectare) and Woodland Flowage (0.41 angler days/acre or 1.01 angler-days/hectare) were ranked 4th and 5th among the 13 bass lakes (unpublished data). Angler use (days/area) on three of these St. Croix watershed bass lakes ranked 1st, 2nd, and 4th among 11 eastern Maine lakes with angler surveys conducted in 2002. The annually consistent higher levels of angler use document the quality of the fisheries in lakes in the St. Croix watershed relative to other lakes in eastern Maine.

Maine is near the northern limit of the range of smallmouth bass. As a result, harvest regulations attempt to ensure that a portion of a spawning population is larger fish, important for maintaining robust populations. These larger fish are also desired by bass anglers, and the size quality of Maine's bass populations is due, in large part, to a strong angler catch and release ethic. Since 1992 bass harvest regulations on Big Lake and Grand Falls Flowage have included a protective slot intended to produce fisheries for quality-sized bass. From 1992 to 2007, a slot limit prohibited the harvest of all bass 12 to 16 in (305 to 406 mm). In 2008 the protective slot size changed to 13 to 18 in (330 to 457 mm). Because the size structure of the Woodland Flowage bass population is different, length regulations are more liberal with a

minimum length of 10 in (254 mm) and harvest limits that vary by season (one bass from April 15 – June 30, three from July 1 – September 30, and no harvest October through December). The objectives of the regulations are to protect most bass during spawning and permit harvest afterwards. During periods when alewives were not present in these lakes, the size of 100 smallmouth bass captured by experimental angling has averaged 11.0 ± 0.3 in (280 ± 7.6 mm) at both Big Lake and Grand Falls Flowage, and about an inch smaller (9.9 ± 0.2 in or 251 ± 5.1 mm) at Woodland Flowage.

Criteria

The number of a juvenile smallmouth bass is one of the primary determinants of the quality of a lake's bass fishery in subsequent years. Year-class strength of young-of-the-year (YOY) smallmouth bass in northern climates, such as eastern Maine, depends on their survival between fertilization and the end of the first growing season in the fall (MacLean, et al. 1981). Poor survival in their first growing season has been linked to the size of males guarding nests (Baylis et al 1993), changes in water level (Ploskey et al. 1996, Neves 1975, Clark et al. 1998), temperature (Shuter et al 1980, 1985, Finlay et al. 2001, Goff 1985, MacLean et al. 1981), and wind (Goff 1985). Male bass construct nests and remain near the nest to drive off intruders and predators. Declines in water temperature often occur after eggs are in the nest, commonly resulting in nest abandonment by the male and a total loss of eggs and fry in those nests.

A single year failure of natural reproduction in eastern Maine does not produce a collapse of smallmouth bass fisheries (Jordan 1990, 1991). Rather, as observed after the 1986 bass year-class collapse in eastern Maine lakes, there was a compensatory rebound of the next two year-classes in 1987 and 1988. Bass spawned in these two years contributed to high quality fisheries (Jordan 1990, 1991) because warm summers and reduced competition with older smallmouth bass resulted in good growth and high first-year overwinter survival.

MDIF&W and DNR biologists believe that at least two consecutive failed year classes are needed to cause a noticeable effect on the adult bass population and thus the fishery (bass size and catch rates). In the early 1980's, Maine and New Brunswick freshwater fisheries biologists saw reproductive failures in sequential years in Spednic Lake (Cronin 1985, Smith 1998) that resulted in the collapse of the fishery. The reproductive failures coincided with the presence of alewife and water level fluctuations during the spawning period. Smallmouth bass YOY abundance increased when anadromous alewives were denied access, lake levels were managed to protect bass spawning habitat, adult bass were stocked, and a catch and release fishery bass was instituted (Smith 1993).

To address the concern that the bass reproductive failures in Spednic Lake were directly linked to alewife presence, this plan uses YOY relative abundance at the end of their first summer as the measure to ensure bass are not negatively affected by the re-introduction of alewife. Data on annual YOY smallmouth bass relative abundance (catch per unit effort or CPUE) collected in a number of lakes in the St. Croix watershed (Table 5) were used to develop criteria for bass reproductive success for lakes that will receive alewives (Big Lake and Grand Falls Flowage). Three other area lakes where alewives do not have access (West Grand Lake, Baskahegan Lake, and Bog Lake in Northfield) were chosen as control lakes because they have similar quality fisheries and YOY CPUE data were available for one of the lakes.

The control lake data will be used to evaluate the likelihood of region-wide reproductive failures, and assumes that reproductive failures due to weather conditions occur similarly across all lakes. This assumption seems reasonable because the 1986 and 1996 year-classes were identified as weak (age 4 or age 5 bass being less than 15 % of a 100 fish sample) on all the St. Croix lakes sampled (Big Lake, Grand Falls Flowage, West Grand Lake, and Woodland Flowage). Both summers were cool and wet. The 1986 region-wide year class failure corresponded to a summer (June to August) with an average temperature of 61.2 F (16.2 C) and 12.6 inches (31.9 cm) of rainfall (Northeast Regional Climate Center) in Maine. The summer of 1996 was also cool (63.4 F or 17.4 C) and wet (13 in or 33 cm).

The smallmouth bass reproductive success criteria were determined from annual CPUE values collected between 1998 and 2004 (Table 4). Criteria were selected based on the knowledge that in most years spawning success and first summer survival are not thought to limit fisheries in the region (Jordan 2005). Thus, CPUE values indicating good juvenile production are expected to occur more than 70% percent of the time (>30th percentile) and poor reproductive success likely to occur in less than 10% of the time (<10th percentile). The CPUE values in the range between, (10th to 30th percentile) are acceptable but may occasionally result in a weak year class.

Lake specific criteria (Table 5) were developed because annual juvenile abundances at the end of the first year are related to conditions in each lake (i.e. the size of the spawning population, area and quality of spawning habitat, productivity, and fish community structure). In the absence of alewives, the relative abundance of juvenile smallmouth bass was higher in Big Lake than Grand Falls Flowage across all sample years, demonstrating these differences. Because of the limited number of years in the baseline data, percentiles were calculated using the natural logs of CPUE values from each lake.

Table 4. Juvenile smallmouth bass catch per unit effort from electrofishing (YOY / 1,000 sec) from Big Lake, Grand Falls Flowage, and West Grand Lake, 1998-2004.

Year	Big Lake	Grand Falls Flowage	West Grand Lake
1998	29	13	14
1999	28	15	26
2000	20	7	11
2001	16	14	7
2003	24	8	18
2004	23	8	9

Table 5. Reproductive success criteria and associated percentiles for juvenile smallmouth bass for catch per unit effort (YOY / 1,000 sec) in Big Lake, Grand Falls Flowage, and West Grand Lake.

Category	Color	Percentile Range	Grand Falls Flowage	Big Lake	West Grand Lake
Good	Green	> 30%	>8.7	>20.4	>10.0
Acceptable	Yellow	10% - 30%	6.7 – 8.7	17.2 - 20.4	6.9 – 10.0
Poor	Red	< 10%	<6.7	<17.2	< 6.9

“Traffic lights” were selected to display the results of juvenile bass monitoring (Caddy et al. 2005, Ceriola et al. 2007), with: 1) a CPUE representing good reproductive success being assigned a green “light”; 2) an intermediate CPUE estimate assigned a yellow “light” for acceptable reproductive success that may be cause for concern; and 3) a low CPUE resulting in a red “light” to indicate a poor smallmouth bass reproductive success. Red, yellow, or green lights will be assigned to YOY CPUE for the monitoring and control lakes based on lake specific criteria (Table 5). For control lakes, CPUE resulting in red “lights” would indicate poor smallmouth bass production throughout the region for the year. Therefore, because the detected low reproductive success was explained by weather conditions, any corresponding red “lights” in monitoring lakes for that year would be adjusted up one category (to yellow). These adjusted indices will be used to describe the YOY smallmouth bass status in monitoring lakes for the year.

MONITORING PLANS

Only two data inputs are used in the decision framework. The first is the smallmouth bass YOY abundance index for five lakes (Big Lake, Grand Falls Flowage, West Grand Lake, Bog Lake and Baskahegan Lake). Annual YOY smallmouth bass CPUE monitoring will be conducted in late September. For the first five years there will be two data recording methods. Biologists tasked with the monitoring will follow the methods used to collect the baseline data (Jordan 1988) and they will also record the numbers of fish captured for a standard number of seconds of electrofishing time (similar to unpublished data from NBDNR on Woodland Flowage 2005).

The second input to the decision framework is the alewife abundance time series at Milltown. Annual alewife targets within the plan are based on an average density of spawners in the lakes accessible to alewives. Alewife ascending the fishway at Milltown will be counted from the beginning to the end of the run. Two options exist for the counts: partial counts or total counts, and two methods are available for the counts: actual counts of alewife as they ascend the ladder by personnel at the ladder, or collecting video of the run for counting at a later date. Protocols for counts by personnel as fish ascend the ladder include collecting biological data (see additional data section below).

Alewife abundance will vary annually in the accessible lakes, in part as a result of effectiveness of passage at both Woodland and Grand Falls fishways. Especially at high spawner numbers, upstream fish passage inefficiencies could result in delays and stockpiling of alewives below any or all of the dams in the system. If alewife numbers below Milltown, Woodland, and Grand Falls dams become a problem, agencies may need to work with dam owners to improve passage efficiency.

Additional Data to Assist in Validating Targets, Criteria, and Decision Rules

Habitat Accessibility Field visits will be scheduled over several years to visually evaluate alewife passage into lakes and verify the older information used to include or exclude lakes in Table 1.

Smallmouth Bass In the first years of the plan, data will be gathered to evaluate and develop YOY CPUE estimates for each lake based on multiple sites, while continuing to calculate it

based on a total ratio of catch divided by time. Two of the control lakes have little or no background data, so the first five years will be needed to develop the expected CPUE distribution. There was only weak evidence to link low reproductive success, as defined by the criterion, and fisheries year class failures. Therefore, to confirm the link, a 100 bass sample will be angled (Jordan 1991) four or five years following any year that YOY CPUE is below the 10th percentile for that lake. Further, to confirm the assumption that thermal conditions among the monitoring and control lakes are similar within years, StowAway water temperature loggers will be deployed at each lake from May through the first week of November for no more than three years. If available, older data will also be used to evaluate this assumption. The length (mm) and weight (to nearest 0.01g) of each bass captured will be measured. Each year, summary data on weather, water management, dam maintenance, and catastrophes (e.g. forest fires, hurricanes) for the St. Croix watershed will be compiled to assist in understanding spring and summer conditions in the monitored lakes.

Alewife Biological characteristics of the alewife spawning population are needed to refine the population targets and rebuilding timeline. There are two interrelated considerations for sampling biological characteristics: sample size and obtaining a sample representative of the population. The purpose of the sampling is to assign fish to species, sex, age and previous spawning categories. Assuming two sexes, maturation at ages 3 to 6 and a maximum age of 9, there would be 37 categories for which proportions would need to be assigned. Alewife runs are stratified with respect to sex (females are generally earlier) and age (older fish are generally earlier). Ad-hoc sampling without consideration of this stratification is almost always non-random and may lead to erroneous estimates of ages, sex ratios and other characteristics. Additionally, sample sizes need to be sufficient to estimate proportions in each category. However, a random sample can be obtained relatively easily in conjunction with counts at a fishway. Recording species, sex, fork length, and weight, and collecting scales from up to 1,000 live fish (10 out of each 1,000 ascending the ladder) will be sufficient. Ageing a random sample of 500 of the scales collected in the field will produce an unbiased sample from the population.

While the targets are based on returns to Milltown, estimating the number of alewife accessing habitat above Grand Falls Dam (i.e. the number passing the Grand Falls fishway) would provide data on fishway passage efficiencies and spawner distribution within the watershed. Because only alewife numbers are needed the use of video is a practical option (Davies et al. 2007).

DECISION PROCESS FOR ALEWIFE PASSAGE BASED ON BASS CRITERIA

Overview

This process is intended to allow for reasonably fast rebuilding of the alewife population, while ensuring that negative effects on the smallmouth bass fishery, if detected, can be acted upon rapidly. None of the decisions in this process depend on a long-term spawning escapement goal. Under the plan, the alewife population will be allowed to grow unchecked to an escapement target of 146,316 alewife for the accessible habitat (6 alewife/acre or 14.8 alewife/hectare), after which population growth will be: 1) restricted to a maximum of 50% increase per year if no negative effects on smallmouth bass YOY are detected; 2) held at the previous annual target if negative effects are suspected; 3) or reduced if negative effects are

detected. The decision to allow the population to grow to 6 fish/acre (14.8 fish/hectare) before implementing restrictions was made to allow the population to reach the stocking density used in Maine to restore a population into historic spawning habitat. During rebuilding there will be times when the population growth rate is less than 50% per year or times when the population will decline. The process addresses this natural variability in two ways: by using a three-year moving average alewife abundance to calculate annual targets and modifying the target calculation if the population declines.

Linking the Bass Recruitment Index to Changes in Annual Alewife Spawner Target

Establishing the spawner target for the next year requires six data inputs for smallmouth bass: the adjusted (see pages 12) recruitment index (i.e. traffic light colors) for Big Lake and for Grand Falls for each of the last three years. These will be some mixture of green, yellow, and red lights (Figure 2).

	Year 1	Year 2	Year 3
Big Lake	Yellow	Green	Green
Grand Falls	Red	Green	Yellow

Figure 2. An example of traffic light input to the decision framework that are based on comparing annual CPUE smallmouth bass data with criteria in Table 5 and adjusting for control lake conditions.

The lights are scored to facilitate decisions: -1 for red (unacceptable conditions), 0 for yellow (the cautionary zone), and +1 for green (good conditions). The resulting six values are summed, and the total score is used to determine whether the annual spawner target for the next year should be increased (with a positive score), decreased to the previous level (a negative score) or should remain the same (a score of zero). An exception to these decisions occurs if there are two consecutive years of red lights in any one lake (after raw scores are adjusted based on results from control lakes); then the next annual target will be decreased to avoid the potential for three poor bass recruitments to occur in a row (Table 7).

Determining the Annual Alewife Spawner Target

Once the number of alewife spawners reaches 6 alewife/acre (14.8 fish/hectare), a constraint is placed on how rapidly the population is allowed to grow. The annual spawner target is derived using the three-year mean population size corresponding to the bass recruitment index. Increases occur in steps of 50%. As an example, if the three-year average population size is 200,000 alewife, and a positive score is obtained from the bass recruitment index, then the annual target is increased to 300,000 for the next year. If the score was a zero, then the spawner target for the next year would stay the same; at 200,000 alewife. If a negative score is obtained, then the spawner target returns to the previous lower target. This target remains in effect until the year that it is reached, after which a decision is made to increase it, to decrease it, or leave it the same based on the juvenile bass score.

Population growth is expected to be variable and abundance is expected to decrease in some years. When there is a decrease in alewife population size, if the bass recruitment score indicates that the spawner target should be decreased, the decrease is determined from the

current three-year mean abundance, not the current spawner target. For example, say the population size reached 200,000 alewife, received a positive score and the target was increased to 300,000. Then, as a result of natural variability, the alewife population decreased to 150,000 for a few years, after which there was a negative score. The spawner target would be reduced to the previous level below 150,000 alewife that received a positive score. The framework would then be implemented from that level, and based on the bass recruitment score; the spawner target for subsequent years would be either increased, decreased, or held at the same level. This rule is to ensure that alewife do not negatively affect bass recruitment.

Table 7. Scores corresponding to the various combinations of green, yellow and red indicators. For example, in row 2, the score is calculated as $(4 \times +1) + (0 \times 1) + (1 \times -1) = 3$, a positive score. Exceptions occur if red indicators appear in two consecutive years in the same lake. Then instead of the expected change from a positive score, the spawner target would be reduced to avoid potentially having three poor bass recruitment years in a row.

Number of indicators that are:			Total	
green	yellow	red	Score	
4	2	0	4	
4	1	1	3	
4	0	2	2	Exception
3	3	0	3	
3	2	1	2	
3	1	2	1	Exception
3	0	3	0	Exception
2	4	0	2	
2	3	1	1	
2	2	2	0	Exception
2	1	3	-1	
2	0	4	-2	
1	5	0	1	
1	4	1	0	
1	3	2	-1	
1	2	3	-2	
0	6	0	0	
0	5	1	-1	

The following details the decision process that will be implemented in the third autumn after the plan is in effect and each subsequent autumn. A hypothetical example is also provided (Figure 3).

1. Calculate the bass abundance score based on the previous three years.
 - If the score is positive, go to step 2.
 - If the score is zero, go to step 3.
 - If the score is negative, go to step 4.
2. Did the alewife population meet the spawner target in the last year?
 - If yes, calculate the mean number of spawners for the last three years and multiply it by 1.5 to obtain the new spawner target.
 - If no, the spawner target remains unchanged.
3. The spawner target remains unchanged.
4. Is the mean escapement for the last three years above the previous spawner target?
 - If yes, reduce the spawner target to the previous level.
 - If no, reduce the spawner to the last level below the current 3-year mean population size that produced a positive score.

	Yr1	Yr2	Yr3	Yr4	Yr5	Yr6	Yr7	Yr8	Yr9	Yr10	Yr11	Yr12	Yr13
Target Escapement	146,316	146,316	146,316	178,158	178,158	242,237	242,237	242,237	242,237	323,619	242,237	242,237	387,237
# Alewife Passed	90,000	120,000	146,316	160,000	178,158	175,000	180,000	225,000	242,237	290,000	242,237	242,237	387,237
Bass Index	+	+	+	+	+	+	+	+	+	-	0	+	+
Target Reached	NO	NO	YES	NO	YES	NO	NO	NO	YES	NO	YES	YES	YES
Target Change Decision	Hold	Hold	Increase	Hold	Increase	Hold	Hold	Hold	Increase	Decrease	Hold	Increase	Increase
3 year average Escapement	na	na	118,772	142,105	161,491	171,053	177,719	193,333	215,746	252,412	258,158	258,158	290,570

Figure 3. A hypothetical example of the decision process that integrates juvenile bass abundance (bass index score) and the three year moving average of alewife passed above Milltown determine the annual spawner target. Note that in year 3 the number of alewife spawners reaches 6/acre (14.8/ha).

Computer Simulations to Evaluate the Framework

Even if alewife have no negative effect on the bass population, a few years of poor bass YOY abundance could occur by chance (natural variability). This framework has the potential to severely slow alewife population recovery because of these chance events. A computer simulation model was developed to compare how rapidly alewife recovery would occur with and without the annual spawner targets proposed in the plan. The simulations predict how the alewife population might grow during the next 50 years, allowing for natural variability in both the bass YOY index and in the growth rate of the alewife population. Low (25% increase/year) and high (50% increase/year) alewife population growth rates were used in the evaluation. For the higher rate of increase, when this management plan was applied, the time to reach 4.4 million alewives (a potential recovery goal for this evaluation) was slightly more than double the time needed if the population was allowed to grow unchecked. In the lower productivity scenario, when plan decisions were used, population growth to the potential recovery goal was about 10 years slower than without controls. These simulations give some confidence that the provisions in this plan to protect smallmouth bass are not so restrictive that they will prevent alewife from recovering, although they are expected to slow recovery rate. Details on the population simulations are provided in Appendix 1.

ADAPTIVE MANAGEMENT PLAN IMPLEMENTATION

This plan's implementation will require unrestricted alewife passage at both the Woodland and Grand Falls dams. It will also require long-term agreements by government agencies to maintain alewife barriers at Spednic and West Grand Lakes, to monitor and control alewife passage at Milltown in accordance with the decision framework, to monitor the relative abundance of smallmouth bass young-of-the-year populations in selected lakes, and to gather and assess additional data needed to validate and revise the plan in the future (Table 8). Initial agency agreements should cover the first five years of the plan and be renewed when the number of spawners reaches 6 alewife/acre (14.8/hectare) and at five year intervals thereafter in conjunction with a full plan review.

A small interagency group should be tasked with applying the decision process and reporting the outcomes to all parties. Further, to maintain an adaptive plan, that same group should reevaluate the long-term alewife spawning escapement goal, bass reproductive success criteria, and decision rules in five years or when alewife spawners are approximately 6/acre (14.8/ha) and at five year intervals thereafter. Participating agencies will need to review proposed changes to the plan, reaffirm their continued participation and renew agreements.

Eighteen tasks were identified to either implement the plan or provide additional data to validate criteria and population recovery goals, and rebuilding projections (Table 8). The agency(ies) most likely to lead a task are identified. Cost of the work, which might be included in an agency(ies) budget or funding sought from outside sources, are estimated. For some tasks, it was difficult to know how many lakes or years of sampling are needed (i.e. 100 bass angling sample) and the cost for a unit of work is provided.

This plan was prepared at the request of the International Joint Commission's International St. Croix River Watershed Board, and is now submitted to that Board for its consideration and possible future action.

Table 8. Proposed implementation tasks, with associated costs in dollars (US or Canada noted).

Area	Task	Schedule	Likely Lead	Notes	Unit	Cost
Written Protocols	Develop written monitoring protocols for juvenile smallmouth bass monitoring	2012	IF&W	in Plan Group Work Report	Document	\$3,000 US
	Develop written monitoring protocols for smallmouth bass experimental angling	2012	IF&W	in Plan Group Work Report	Document	\$3,000 US
	Develop written monitoring protocols for alewife counting and biological sampling at Milltown Fishway	2012	USFWS, DFO, DMR	in Plan Group Work Report	Document	\$4,000 US
	Develop written monitoring protocols for alewife video counting at Grand Falls Fishway	2012	DFO	in Plan Group Work Report	Document	\$3,000 Can
	Develop easily used Framework "workbook"	2012	DFO	in Plan Group Work Report	Workbook	\$7,000 Can
Monitoring	Monitor YOY smallmouth bass relative abundance in 5 lakes	annual	IF&W	Assistance from DMR, NB DNR	Year	\$7,100 US
	Evaluate influence of low smallmouth bass reproductive success on age 4 or 5 year class strength in the fishery	as needed in first 10 years	IF&W	Assistance from DMR, DNR	Year and Lake	\$4,100 US (Big) \$5,300 US (Grand Falls Flowage)
	Alewife counts and biological sampling at Milltown Fishway	annual	DFO, USFWS	Unfunded after 2011	Year	\$13,000 Can
	Alewife video counting at Grand Falls Fishway, equipment	One time		Unfunded	Equipment	\$6,000 Can
	Alewife video counting at Grand Falls Fishway, operations	annually for 5 years		Unfunded	Year	\$2,000 Can
	Lake water temperature records and analyses	annually for 3 years	IF&W	Equipment, staff time, travel	Year	\$2,000 US
Control Passage	Block Spednic fishways as directed by DFO	annual	Domtar	Fishway maintenance	Year	\$600 US
	Block West Grand fishways as directed by IF&W	annual	Domtar	Fishway maintenance	Year	\$600 US
	Limit escapement at Milltown to plan targets	annual	DFO	Agency or Contracted	Year	\$1,000 Can
Plan	Data assembly and analyses	annual	Plan Group	Staff time, travel, meeting	Year	\$11,000 US
	Report to IJC and jurisdictional agencies	annual	Plan Group	Staff time, travel, meeting	Year	\$3,000 US
	Review plan, year 5 and at intervals through alewife recovery	As needed	Plan Group	Staff time, travel, meeting	Review	\$25,000 US
Fisheries	Plan and manage fisheries on the alewife population when appropriate	As needed	DFO- Canada DMR- US	Agency Mission	Year	X

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APPENDIX 1. Evaluation of the Decision Framework

The decisions about whether or not to increase the alewife spawner target are based on the status of the smallmouth bass YOY recruitment index. Given that the bass index is expected to undergo natural variation, the framework has the potential to restrict, potentially severely, alewife population recovery if a few years of poor bass YOY abundance occur by chance, even if alewife have no impact on the bass population. To evaluate the feasibility of recovering alewife using this plan, as well as to evaluate the extent to which alewife recovery will be slower than would occur naturally, a computer simulation model to examine how rapidly alewife recovery would occur with and without the constraints of this adaptive management plan. These simulations are predictions of how the alewife population may grow during the next 50 years, allowing for natural variability in both the bass YOY index and in the growth rate of the alewife population. These simulations were carried as follows:

1. Values for the YOY bass index were drawn at random for both Grand Falls Flowage and Big Lake for each of the next 50 years. The average values and the variability in these values are based on the observed data for these indices. The annual scores for the bass index were calculated as described in the plan.
2. Alewife population growth was simulated using a logistic growth model with an assumed maximum population growth rate and a carrying capacity. In this model, the population growth rate is highest when abundance is low, but decreases to zero growth as the population approaches the carrying capacity. Population growth rates for alewife in the St. Croix are not known, so two scenarios were used for the growth rate: a high productivity scenario in which the population was allowed to increase by 50% per year, and a low productivity scenario in which the population was allowed to increase by 25% per year. The population was projected forward using this model starting at the current abundance, in a way that allowed for random variability but with an increased chance that good years will follow good years and bad years will follow bad (known as autocorrelation). Because of variation, the population growth rate in some years could be considerably higher or lower than the average values of 50% (high productivity scenario) and 25% (low productivity values) that are used.
3. The alewife population was projected forward in two ways:
 - a. The population was allowed to grow unconstrained.
 - b. The population growth was limited using the decision framework described above. In these cases, the spawner target was established using the rules of the plan, and in each year it was either increased, decreased or held at the same level based on the bass YOY index score determined in step one.

In each instance, the population was projected forward 500 times, each time using a different set of random numbers in order to provide an indication of the range of variability that might be expected as the alewife population recovers (Figure 1). These graphics are simulated population trajectories that were used to evaluate how the plan would likely influence rebuilding times in the absence of any negative effects of alewives on smallmouth bass. Rebuilding times are likely to be different because the model does not include any of the river specific factors that will effect the population during rebuilding. In the high productivity scenario, the time to reach the escapement target is slightly more than doubled when this management plan is applied. In the low productivity scenario, less than half the simulated

populations do not reach the escapement target in 40 years with the plan in place. Based on the simulations, the work group believed operating under the plan decision rules would not unduly compromise alewife population growth.

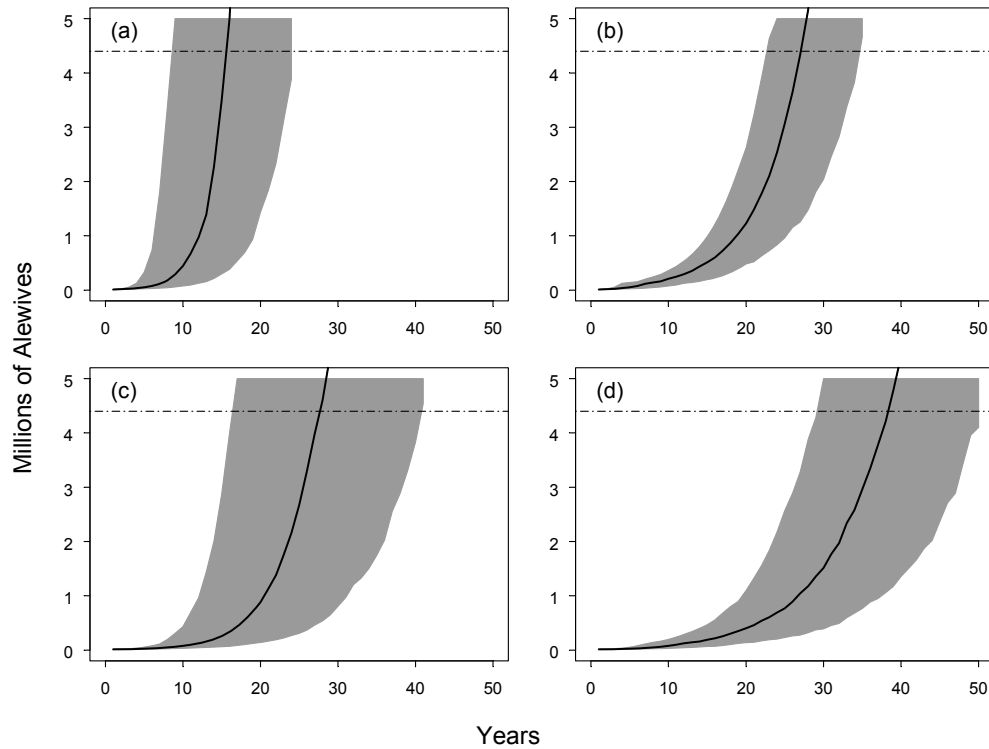


Figure 1. Results of the simulation testing of the management plan. The top row (a and b) show the higher productivity results, the bottom row (c and d) the lower productivity results. The left panels show the population projections in the absence of a management plan, the right panel the population projections with the management plan in place. Each panel shows a summary of 500 simulated population projections. The solid line shows the median abundance in each year: 250 abundances are above this line and 250 are below. The grey shading shows the range containing 90% of the projected abundances and provides an indication of the uncertainty. The horizontal dashed line is the low term escapement target.